UXO CALCULATOR: A NEW STATISTICAL APPROACH FOR DETERMINING UNEXPLODED ORDNANCE (UXO) DENSITY AT ORDNANCE SITES

Arkie Fanning, PE
U.S. Army Engineering and Support Center, Huntsville
ATTN: CEHNC-ED-SY-O
P.O. Box 1600
Huntsville, Alabama 35807-4301
Phone: (256) 895-1762
Fax: (256) 895-1798
E-mail: Arkie.D.Fanning@HND01.usace.army.mil

Category: Detection Technology

Introduction

The U.S. Army Engineering and Support Center, Huntsville (USAESCH) is the mandatory center of expertise for ordnance issues at formerly used defense sites. In this capacity, USAESCH has developed a new statistical tool to estimate UXO density at formerly used defense sites. This tool has been computerized into a program called UXO Calculator. The technical developer of the UXO Calculator methodology is Dr. Bruce Barrett of the University of Alabama. The operational developer is Mr. Arkie Fanning of USAESCH. This paper provides an overview of UXO Calculator, discussing reasons for its development, technical and operational aspects of the tool, and planned UXO Calculator improvements.

Reason for Development

The old suite of statistical tools developed by USAESCH to aid in the investigation of UXO density at formerly used defense sites. (SiteStats/GridStats) was not very user friendly. It was a black box computer program that required the field team to continue to enter data until the computer told them to stop. The new method is more user friendly. It is quick and easy to run and will allow anyone who can use a computer program to estimate how much sampling will be required for a given scenario. The process is still sequential (i.e., the amount of sampling remaining depends on the current number of UXO that has been found), but it is very easy to use and should aid the field team in making field decisions in real time.

A more important reason for developing UXO Calculator was to provide a tool that would answer questions that were not being answered by SiteStats/GridStats. For instance, what is the expected density of UXO in this sector? Before UXO Calculator, an engineer had to use the results of SiteStats/GridStats to determine the sector density (SiteStats/GridStats gave the average results, which is usually different than the expected results). Now, the field team can use the UXO Calculator computer program to

determine the expected results immediately. Another often asked question was, how do you know you are sampling enough to discover if there really is UXO in this sector. This question is easily answered in UXO Calculator. UXO Calculator can show the probability that UXO would have been discovered given any density based on the amount of sampling performed.

UXO Calculator assists the field team in determining their sampling needs based on sector density and not on sector homogeneity. Almost always, more sampling is needed to prove density requirements than to prove homogeneity requirements (the SiteStats/GridStats approach).

UXO Calculator also works better with geophysical discrimination than does GridStats. If a geophysicist picks the anomalies to be investigated, the randomness requirements of the GridStats approach no longer apply. We no longer want to pick random anomalies but, rather, to pick those anomalies that the geophysicist feels are UXO like. This geophysical approach works better with UXO Calculator than with GridStats since it requires that the total amount of area sampled be provided and does not require random selection of anomalies.

Finally, UXO Calculator better fits the mindset of stakeholders. It allows them to determine what the probability is that UXO is present in a sector given that no UXO was found during sampling. It also allows them to determine the logical upper bound of the amount of UXO expected at a site. The statement that there is a 99-percent probability that there are fewer than 10 UXO at this site is much better understood than the old SiteStats/GridStats statement that the site is homogenous and the average density is .05 per acre.

Technical Details

UXO Calculator is based on the negative binomial probability distribution. The negative binomial depends upon only two outcomes - (1) success, meaning that the randomly placed item of UXO is in the investigated region (occurs with probability p), and (2) failure, meaning that the item of UXO is not in the investigated region (occurs with probability $q = 1-p$). The model assumes that there is a uniform probability of UXO occurrence over the site; however, the UXO is assumed to have been deposited randomly. This means that there was an equal likelihood for UXO to fall anywhere in the sector; however, there is not necessarily a uniform distribution of UXO . Detailed mathematical calculations showing how the UXO Calculator design was developed are available to those interested and can be obtained by contacting Arkie Fanning at USAESCH.

UXO Calculator Process

Steps to be followed in using UXO Calculator in the field are presented below:

Develop Statistical Sectors. Statistical sectors are those areas where UXO had the same probability of being deposited. A statistical sector is not necessarily a risk sector. A risk

sector requires that the land be contiguous, have the same physical characteristics, and have the same current and/or future use. A statistical sector requires only that there is an equal opportunity across the sector for UXO to have been deposited. Statistical sectors are still developed by the field team based on their best knowledge of the sites (range fans, open burning/open detonation areas, etc.).

Determine Design Parameters for Each Sector. What is my target density for this sector? If this sector will have substantial human activity (e.g., construction or a day care center), then my target density might be as low as .1 per acre (1 UXO in 10 acres). If it is a wildlife preserve, I may be satisfied with a target density of 1 per acre. The target density is required in order to allow the team to determine the amount of sampling that must be done at the site. Much more sampling is required to conclude that a sector has a density of less than .1 per acre than to conclude that a sector has a density of 1 per acre. The amount of sampling required should be a design parameter based on engineering evaluation/cost analysis (EE/CA) requirements and budget constraints. The field team should know ahead of time the maximum amount of sampling required for each sector.

Determine Sector Appropriateness After Sampling. After sampling has concluded, the field team needs to review the sampling to determine not only the density of the sector but also whether or not the sector is homogenous. The team may use the sectorization method developed for SiteStats/GridStats, or they may use another method (with the approval of USAESCH). The team may choose to resectorize visually. All of the sampling results should be shown on a sector map. The team may be able to see where the UXO is located and draw their sector maps accordingly.

Write a Statistical Report. A statistical report should be a part of the EE/CA. The report should show the design requirements and whether or not those requirements were met. For instance, if the sector requirement was to show (with 90-percent confidence) that there was less than a density of .1 per acre but sampling sufficient to show only .2 per acre was performed, then the design requirements were not met and the report should explain why (e.g., more digs required than were budgeted for). The report should also show the expected density per sector, the 90-percent confidence interval per sector, whether or not the sector was homogenous, and what sectorization method was used to determine the sectorization.

UXO Calculator Current Modules

There are currently six modules in the UXO Calculator computer program. The modules are as follows:

Sector Expected Density - provides the “expected” density of UXO for the sector given the amount sampled and the results of the sampling to date.

Sector Count Probability - provides the probability for a UXO count in the sector (e.g., 90 percent sure that the UXO count is equal to or lower than 200).

Sector Density Probability - provides the probability for a test density (e.g., 90 percent sure that there is less than .5 per acre on average across the sector).

Confidence Level – provides the number of UXO expected in the sector based upon the degree of confidence (e.g., 90-percent confidence level equals 200 or less UXO in the sector).

Variability of Density Estimate - provides both ends of a confidence interval (e.g., 95-percent confidence with 0 found during sampling; maximum UXO expected is 233, minimum UXO expected is 0).

Minimum Discrimination – provides the probability of finding one or more UXO items in an investigated area (e.g., sample 4 percent of a sector, find 0 UXO, be 95 percent sure that the density is less than .1 per acre since, otherwise, at least one UXO would have been found).

Uses of Current Modules

Except for the minimum discrimination module, all of the modules are variations on a theme. The use of these modules is to statistically characterize the amount of UXO at the site (either as a number per sector, a probability, or a density). The minimum discrimination module is used to show that sufficient sampling has been performed. The question often arises, how do you know that sufficient sampling has been performed to ensure the statistics. The minimum discrimination module provides the answer to this question. The module calculates the probability of finding at least one UXO for a given level of sampling (when no UXO was found).

Planned Additions to UXO Calculator

Hypergeometric Module. Often the number of anomalies at a site is known, and we can use the investigation results along with the number of anomalies to perform our statistics. This method is equivalent to the UXO Calculator method but uses the proportion of anomalies investigated as the basis of the statistical predection instead of the proportion of the area that has been investigated.

Sectorization Module. The current UXO Calculator uses either visual sectorization or the SiteStats sectorization methodology. A sector module that will test the hypothesis of uniform probability of UXO at the site is planned.

Resectorization Module. A chi-squared statistic is planned to resector a site when necessary.

Nonuniform Density Estimate. A nonuniform density estimate is planned for the next UXO Calculator. This density estimate will show the worst case density estimate if in fact the UXO fails the uniformity assumption.

Remaining Sampling Required Based Upon a Target Value. Currently, the model cannot be easily used to determine the amount of sampling required after UXO has been found. A module is being planned that will allow the site team to enter a scenario into the program and from that determine the sampling required to meet their needs.

Conclusion

The UXO Calculator methodology can be used to determine the statistical characterization of UXO at an ordnance and explosives site. It can be used to determine how much sampling is required for a given condition, what the current statistical confidence is for the amount of sampling completed, and whether or not sufficient sampling has been completed to show our site statistical requirements. If you wish to have a copy of this tool, please contact Mr. Arkie Fanning of USAESCH.